

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</small>					
1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE Interim Research Performance Report (Monthly)		3. DATES COVERED (From - To) May 1 - May 31, 2013	
4. TITLE AND SUBTITLE Expeditionary Light Armor Seeding Development		5a. CONTRACT NUMBER		5b. GRANT NUMBER N00014-13-1-0219	
		5c. PROGRAM ELEMENT NUMBER		5d. PROJECT NUMBER	
		5e. TASK NUMBER		5f. WORK UNIT NUMBER	
6. AUTHOR(S) Shridhar Yarlagadda, Bazle Haque		7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) UNIVERSITY OF DELAWARE OFFICE OF THE VICE PROVOST FOR RESEARCH 220 HULLIHEN HALL NEWARK, DE 19716-0099		8. PERFORMING ORGANIZATION REPORT NUMBER MONTHLY-2	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research 875 North Randolph Street Arlington, VA 22203-1995		10. SPONSOR/MONITOR'S ACRONYM(S) ONR		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; distribution is Unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT 2D AutoDyn analyses of cylinder impact on ceramic plate have been conducted to identify the mesh size needed to capture detail crack growth in ceramic tiles Steel 4340 is used for the projectile and AutoDyn SiC material properties are used for the ceramic tile Mesh sensitivity analysis is performed using four different square mesh sizes: 0.50-mm x 0.50-mm square mesh 0.40-mm x 0.40-mm square mesh 0.30-mm x 0.30-mm square mesh 0.20-mm x 0.20-mm square mesh Results shows that 0.20-mm mesh size provides a fracture pattern that may be considered acceptable for analysis A conico-cylinder projectile is also used to study the fracture behavior with 0.20-mm mesh size We will develop 3D FEMs for further AutoDyn analyses An undergraduate student is working in the Summer 2013 session, and we are planning to recruit a graduate student in the Fall					
15. SUBJECT TERMS 2D AutoDyn modeling, cylinder impact, conico-cylinder impact, fracture pattern, mesh sensitivity					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UU			UU	15	Shridhar Yarlagadda
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code) 302-831-4941

20130614019



**MONTHLY REPORT**  
**MAY 2013**

**MODELING AND SIMULATION OF CERAMIC  
ARRAYS TO IMPROVE BALLISTIC  
PERFORMANCE**

# Monthly Report for May 2013



## ABSTRACT

- ☐ 2D AutoDyn analyses of cylinder impact on ceramic plate have been conducted to identify the mesh size needed to capture detail crack growth in ceramic tiles
- ☐ Steel 4340 is used for the projectile and AutoDyn SiC material properties are used for the ceramic tile
- ☐ Mesh sensitivity analysis is performed using four different square mesh sizes:
  - ☐ 0.50-mm x 0.50-mm square mesh
  - ☐ 0.40-mm x 0.40-mm square mesh
  - ☐ 0.30-mm x 0.30-mm square mesh
  - ☐ 0.20-mm x 0.20-mm square mesh
- ☐ Results shows that 0.20-mm mesh size provides a fracture pattern that may be considered acceptable for analysis
- ☐ A conico-cylinder projectile is also used to study the fracture behavior with 0.20-mm mesh size
- ☐ We will develop 3D FEMs for further AutoDyn analyses
- ☐ An undergraduate student is working in the Summer 2013 session, and we are planning to recruit a graduate student in the Fall 2013 session

## SUBJECT TERMS

- ☐ 2D AutoDyn modeling, cylinder impact, conico-cylinder impact, fracture pattern, mesh sensitivity

# Axi-Symmetric Model Geometry



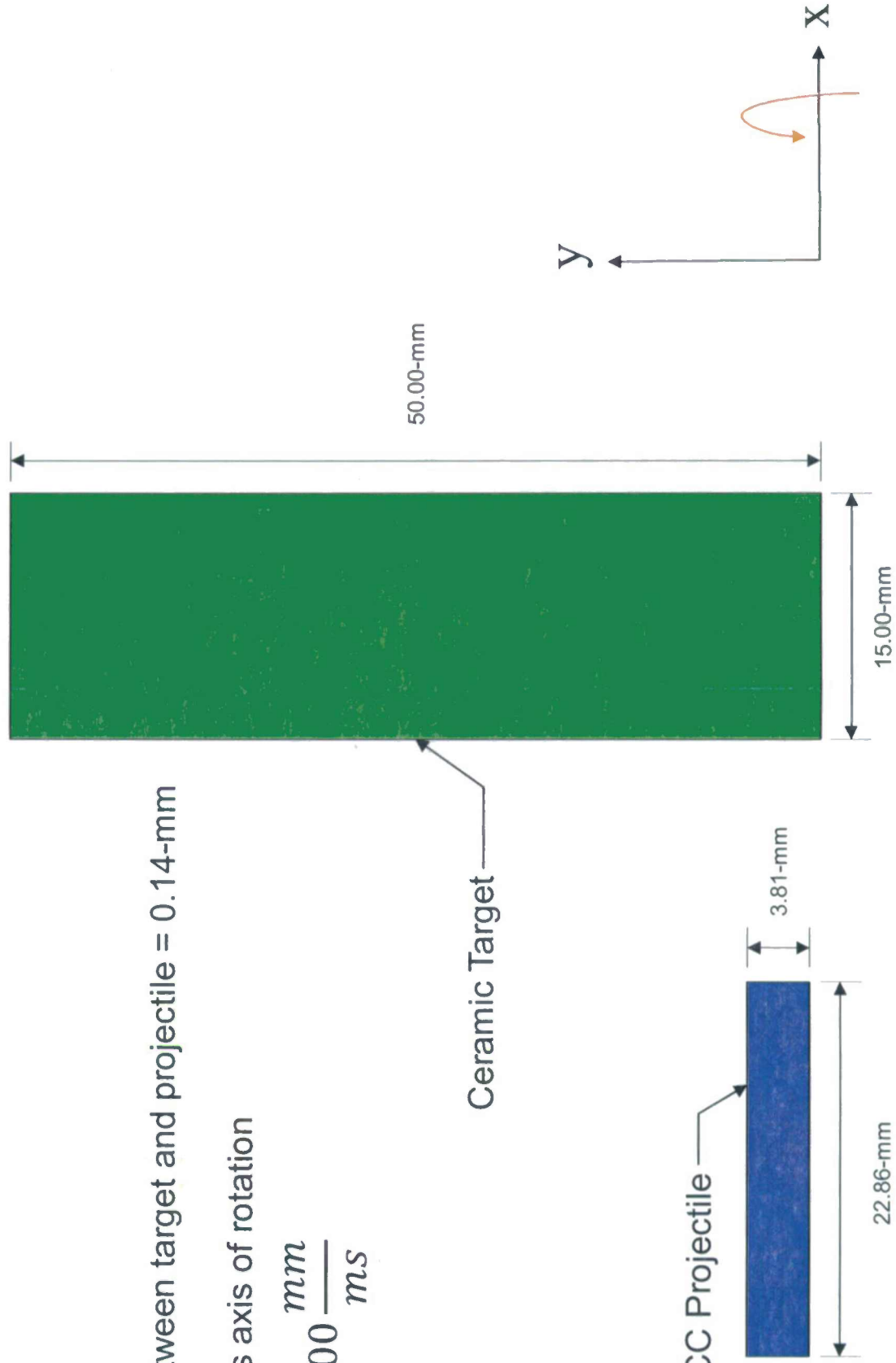
Gap between target and projectile = 0.14-mm

X-axis is axis of rotation

$$V_P = 500 \frac{\text{mm}}{\text{ms}}$$

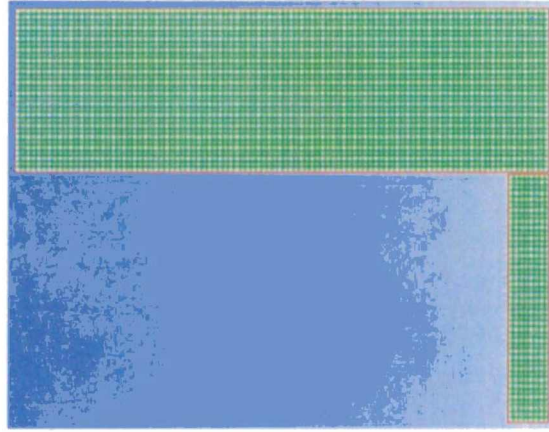
Ceramic Target

RCC Projectile

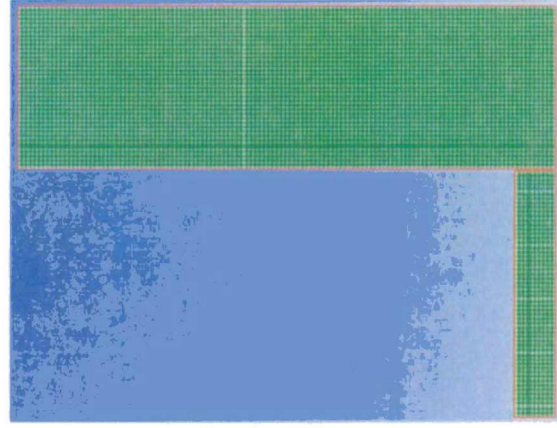




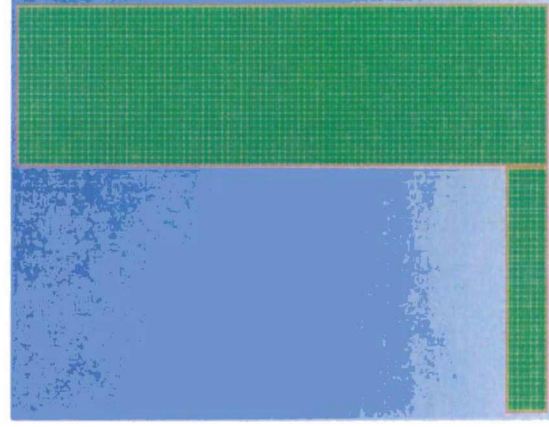
# Different Mesh Sizes Investigated



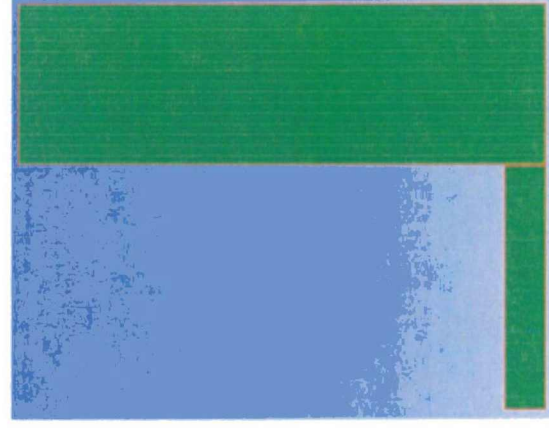
0.50-mm



0.40-mm

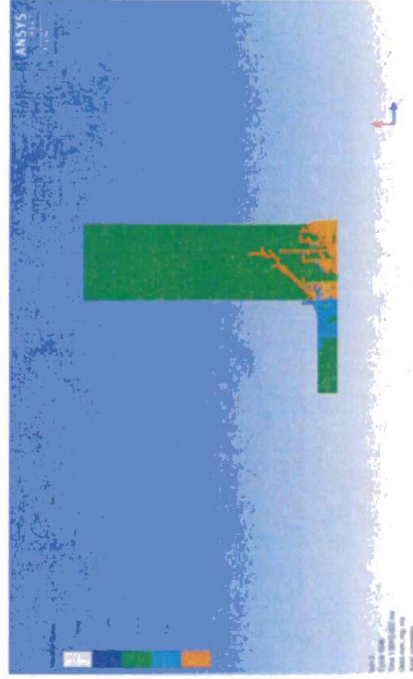


0.30-mm

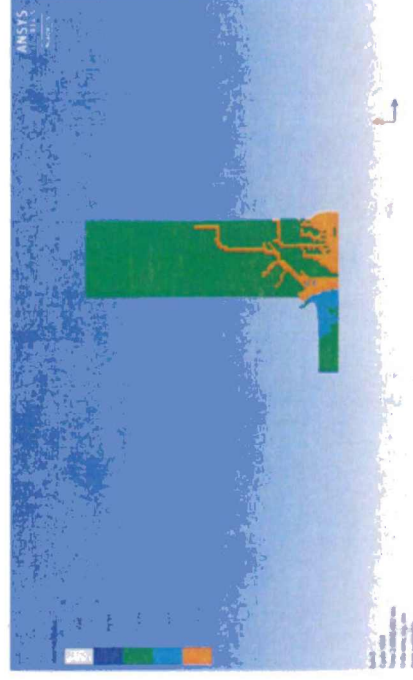


0.20-mm

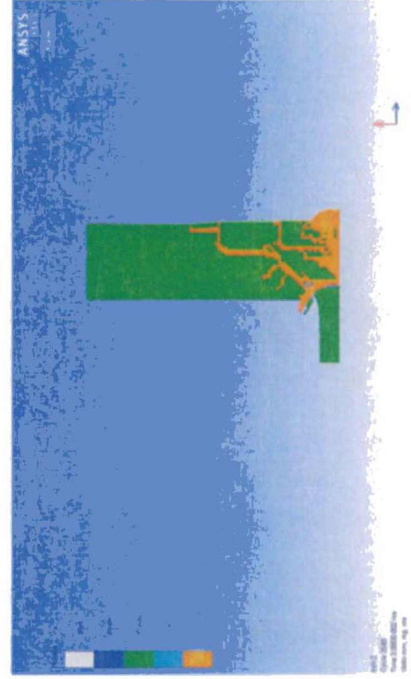
# Fracture Pattern for 0.50-mm Mesh



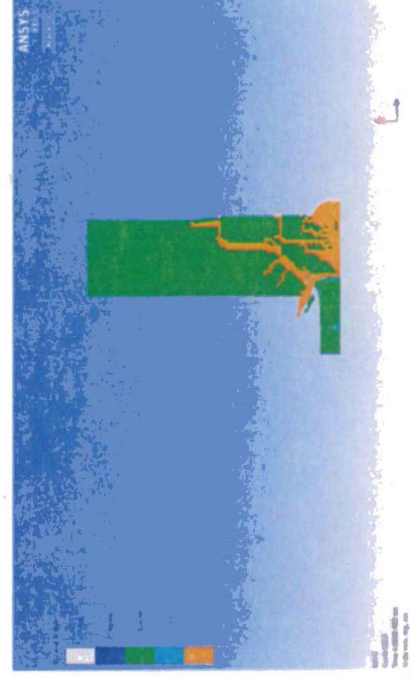
0.010-ms



0.020-ms

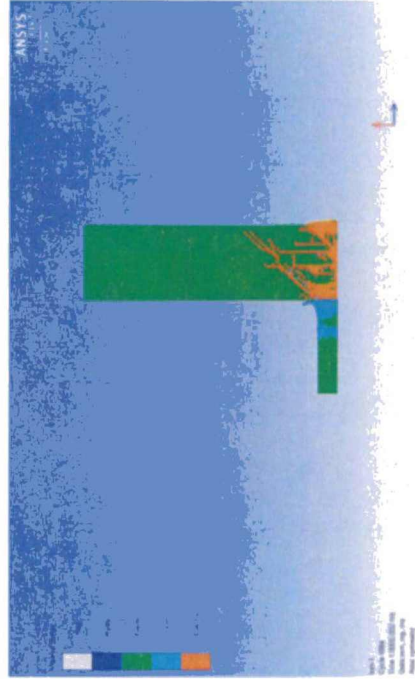


0.030-ms

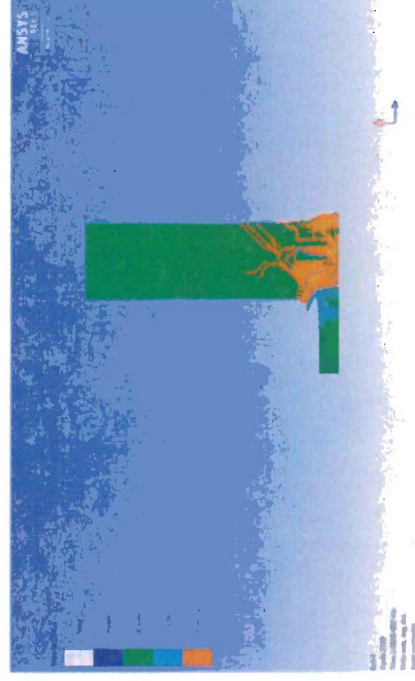


0.040-ms

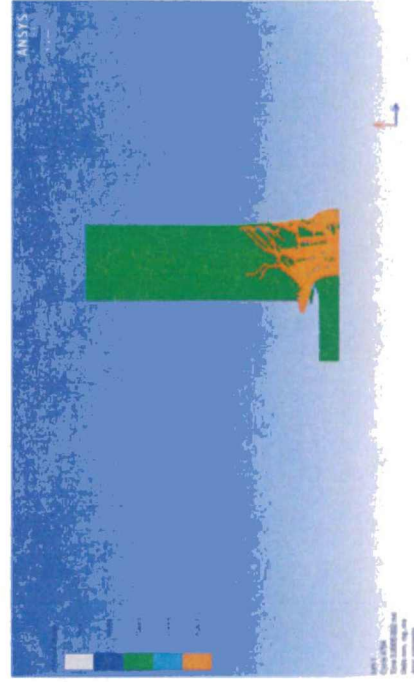
# Fracture Pattern for 0.40-mm Mesh



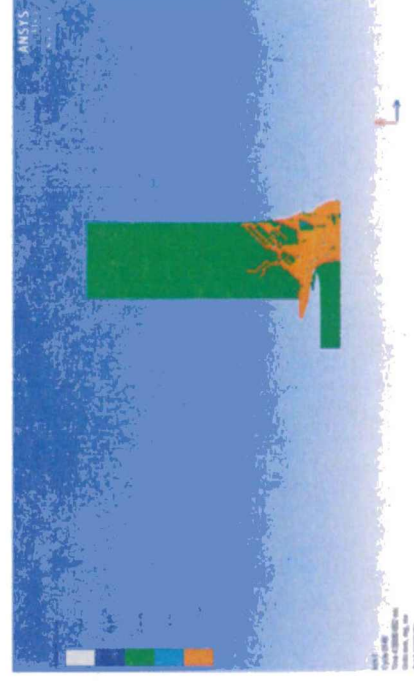
0.010-ms



0.020-ms



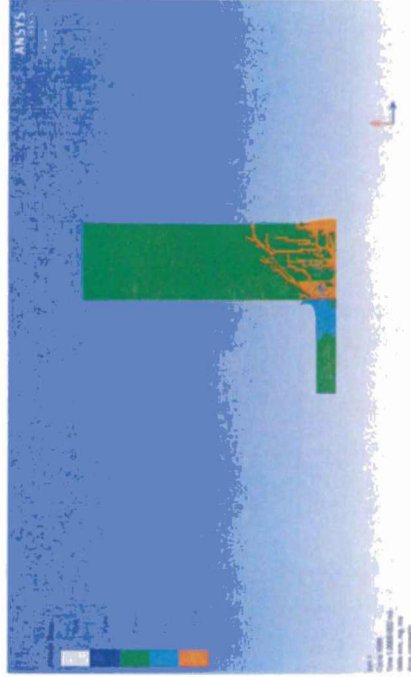
0.030-ms



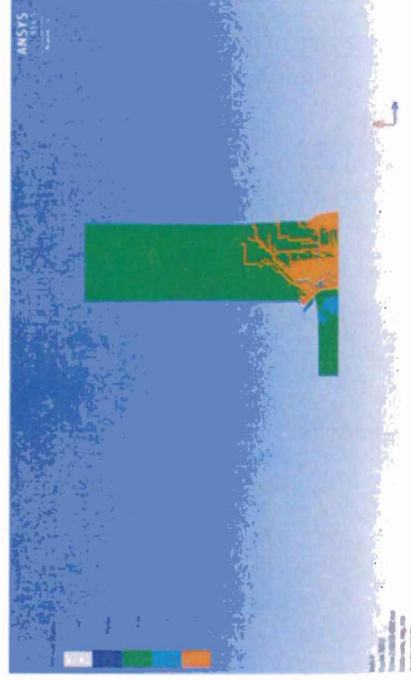
0.040-ms



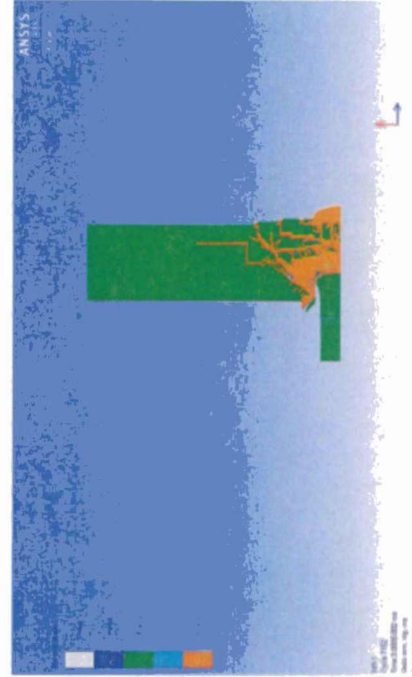
# Fracture Pattern for 0.30-mm Mesh



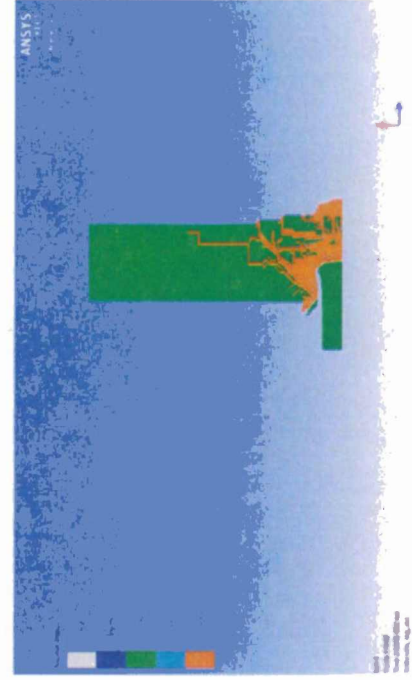
0.010-ms



0.020-ms



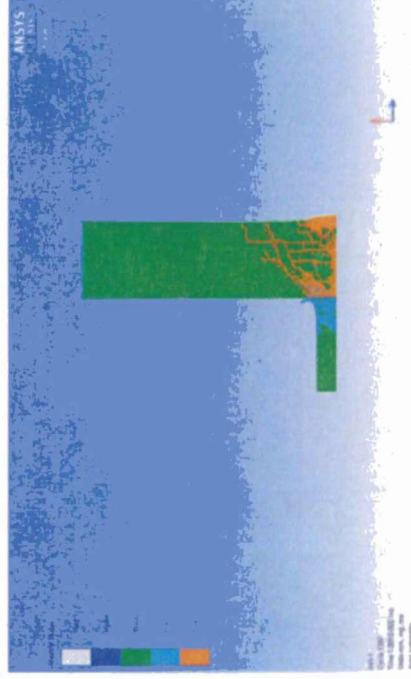
0.030-ms



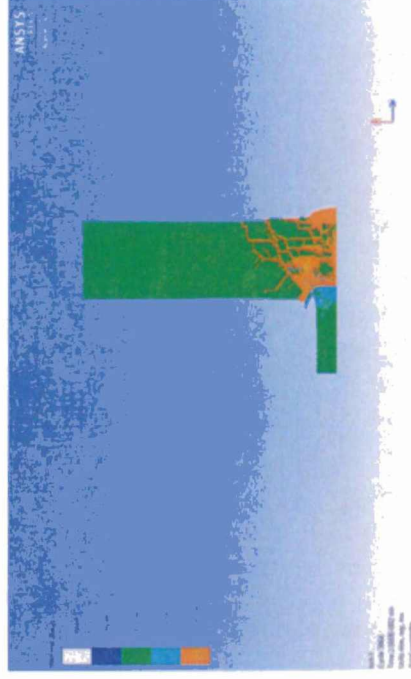
0.040-ms



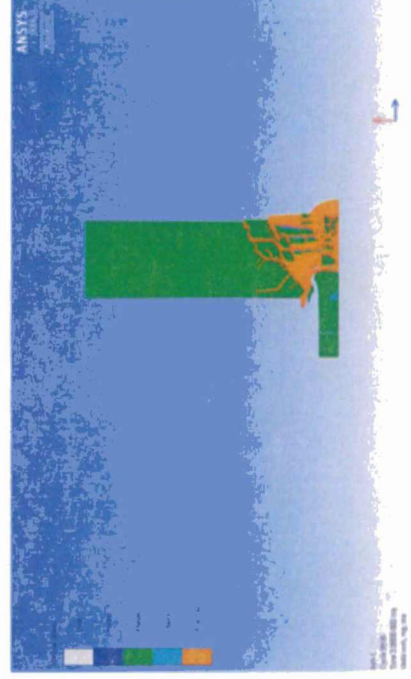
# Fracture Pattern for 0.20-mm Mesh



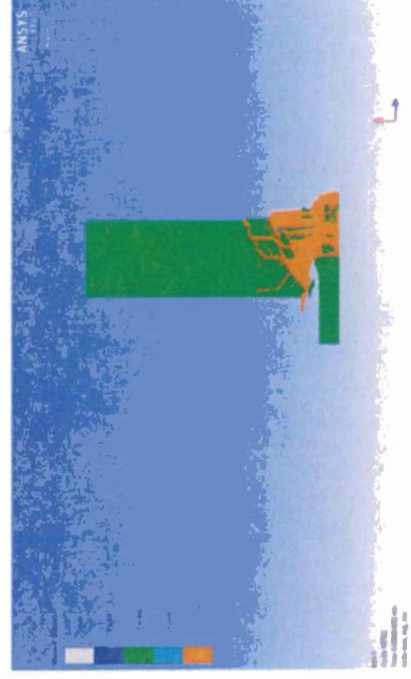
0.010-ms



0.020-ms



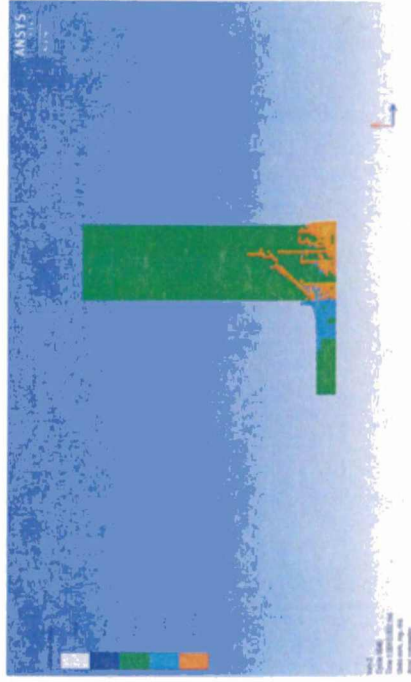
0.030-ms



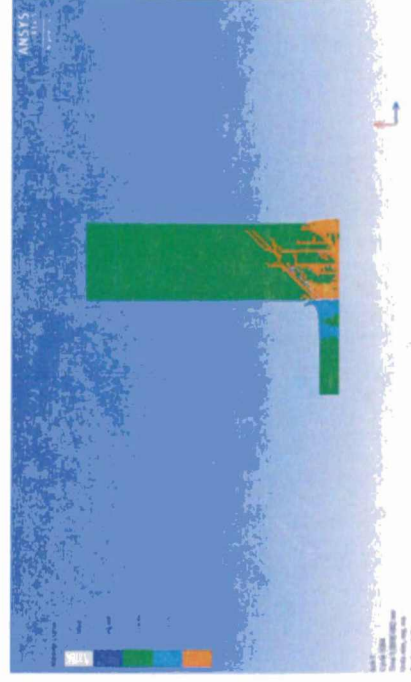
0.040-ms

# Fracture Patterns for All Mesh Sizes

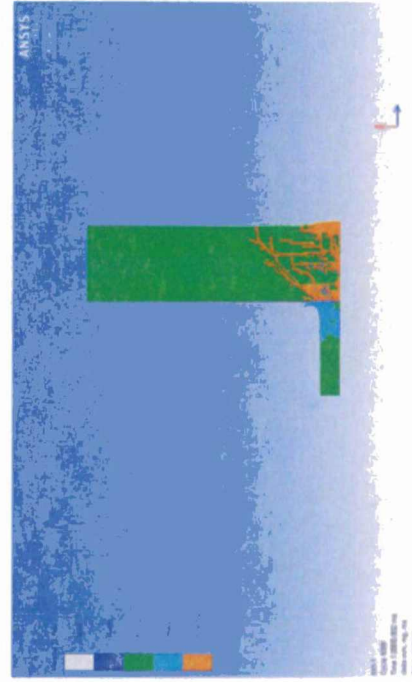
$t = 0.010\text{-ms}$



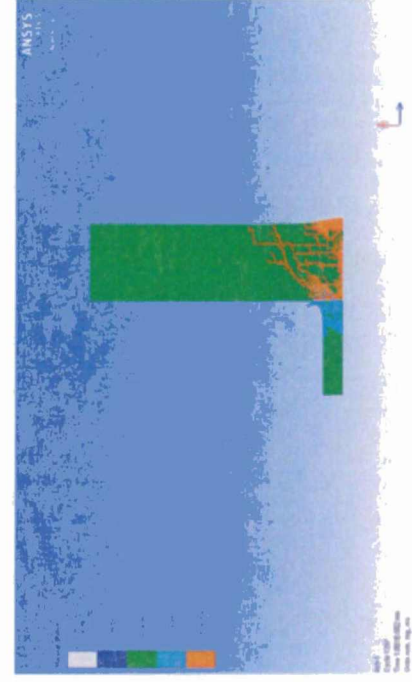
0.50-mm



0.40-mm



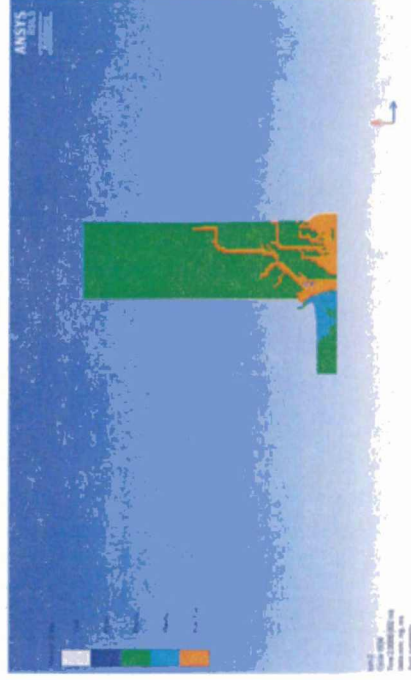
0.30-mm



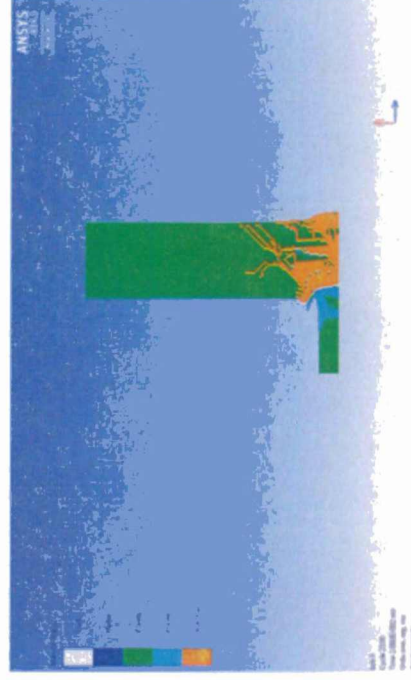
0.20-mm

# Fracture Patterns for All Mesh Sizes

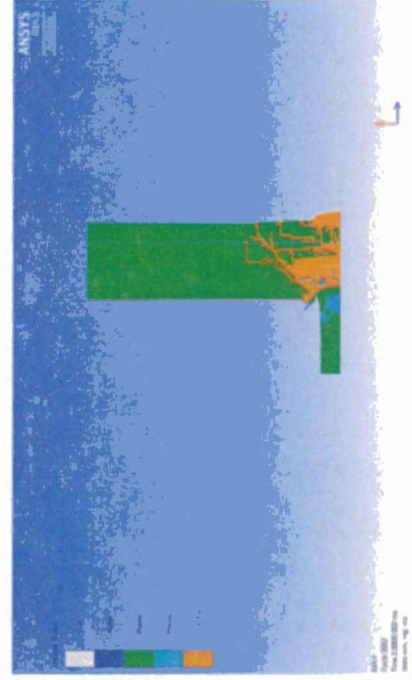
$t = 0.020\text{-ms}$



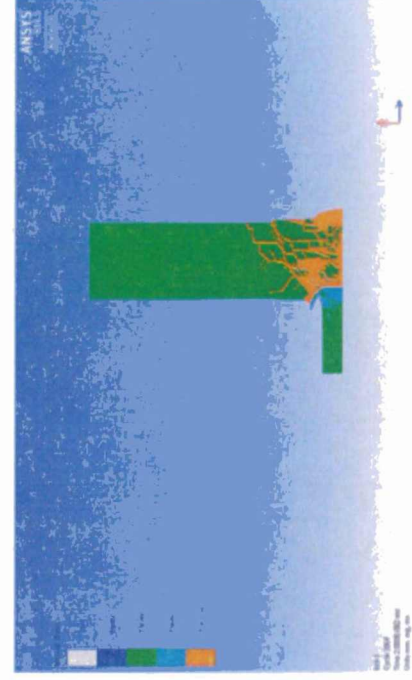
0.50-mm



0.40-mm



0.30-mm

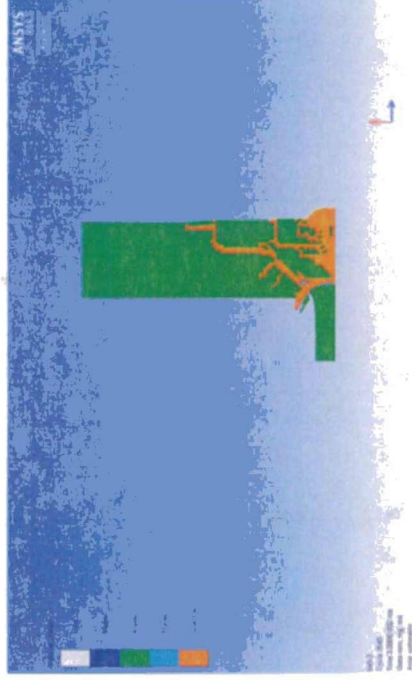


0.20-mm

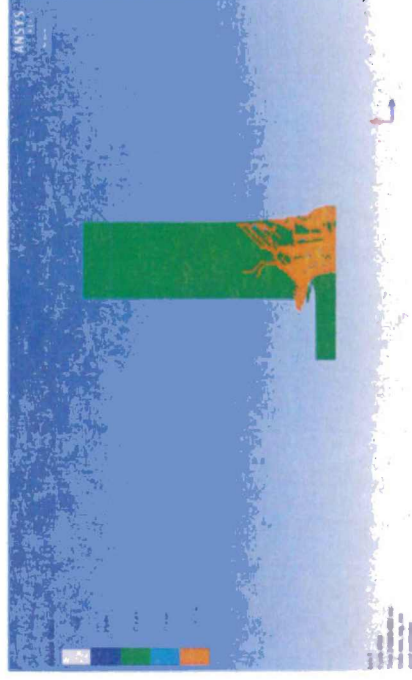


# Fracture Patterns for All Mesh Sizes

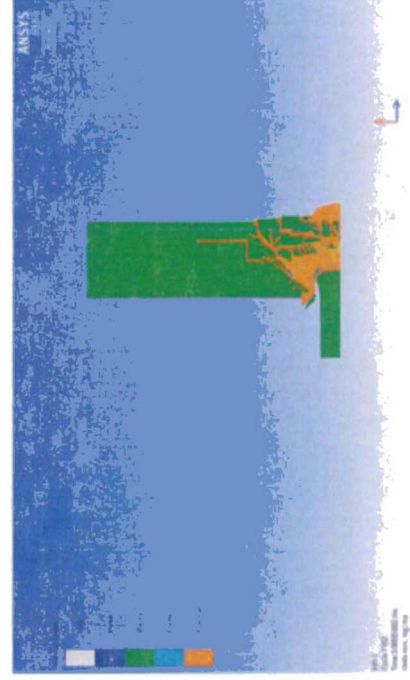
$t = 0.030\text{-ms}$



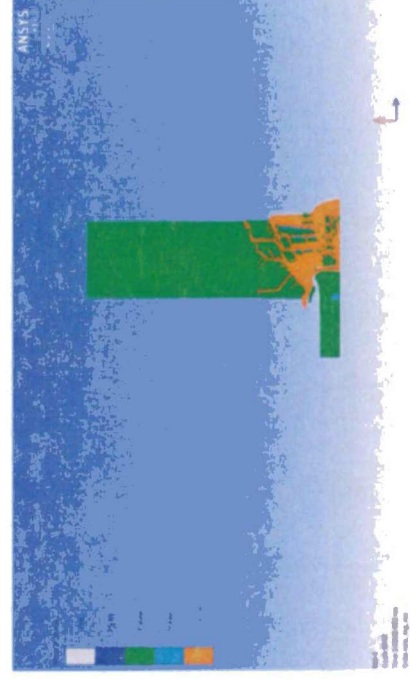
0.50-mm



0.40-mm



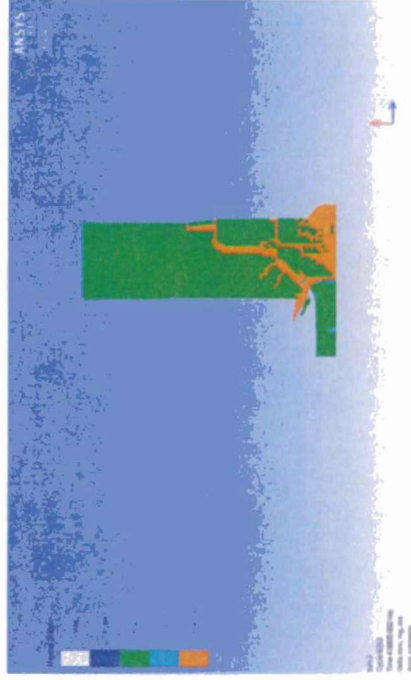
0.30-mm



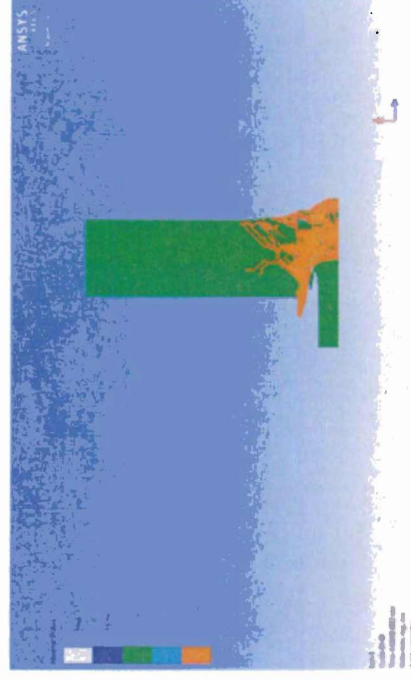
0.20-mm

# Fracture Patterns for All Mesh Sizes

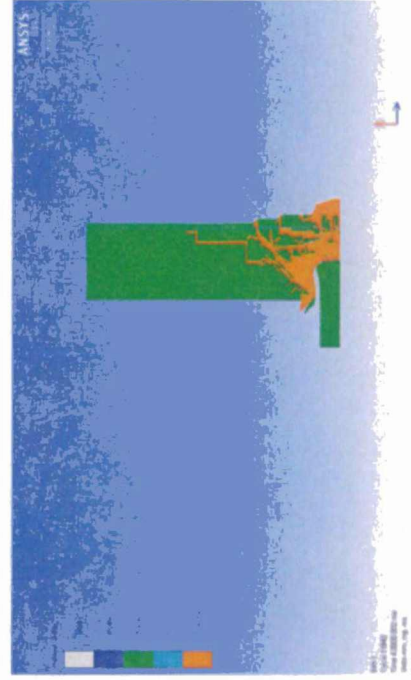
## $t = 0.040\text{-ms}$



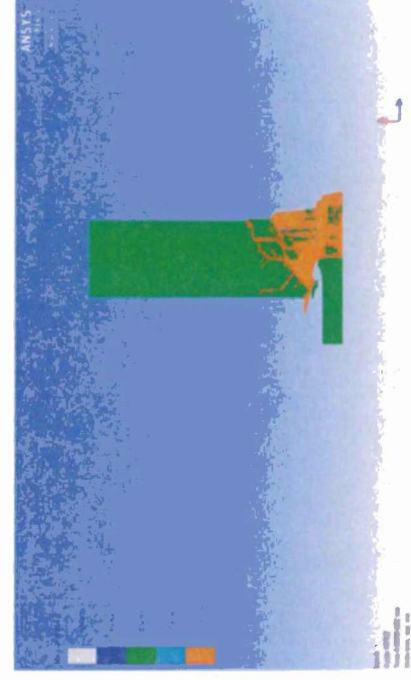
0.50-mm



0.40-mm



0.30-mm



0.20-mm

# Axi-Symmetric Model Geometry



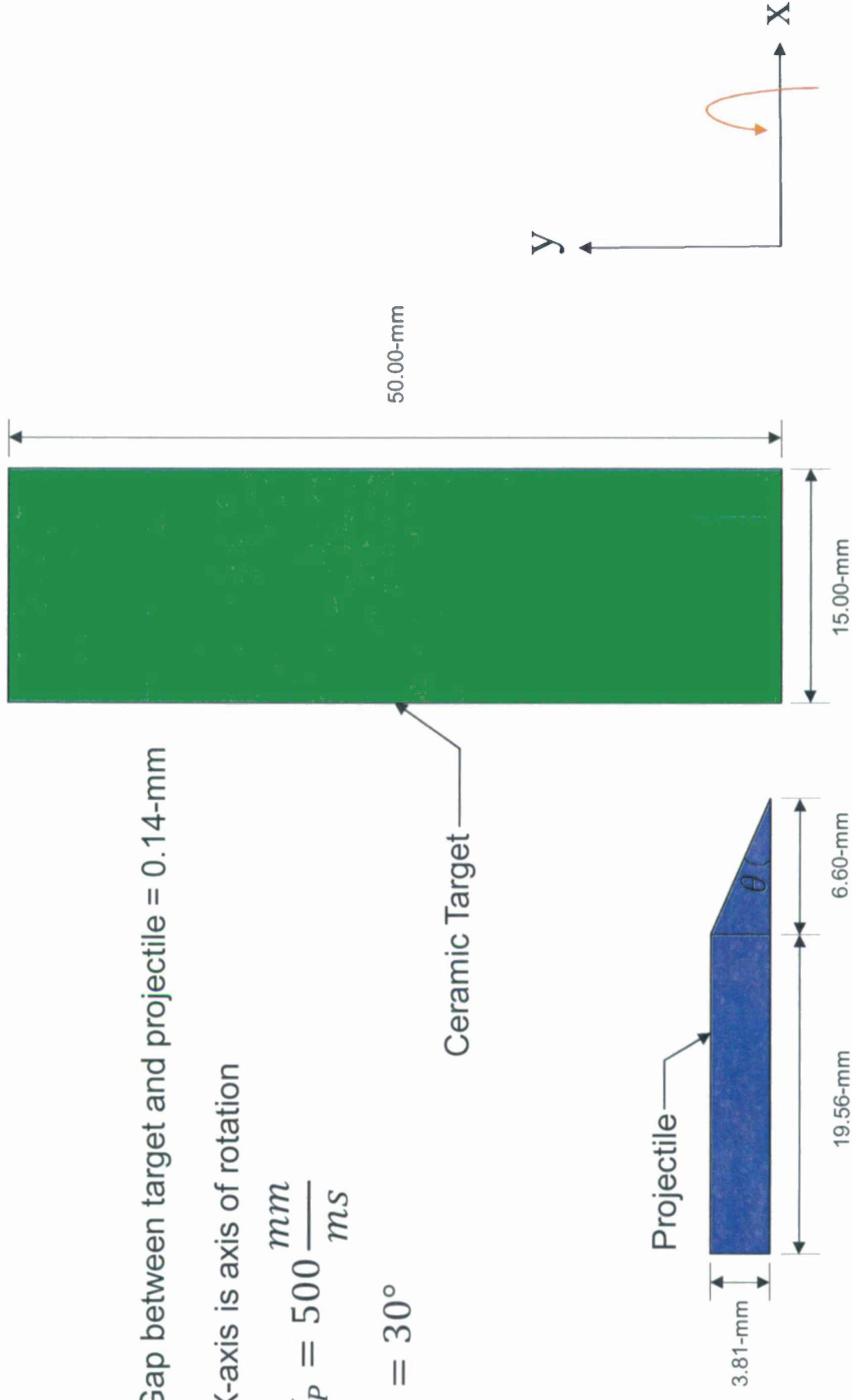
Gap between target and projectile = 0.14-mm

X-axis is axis of rotation

$$V_P = 500 \frac{\text{mm}}{\text{ms}}$$

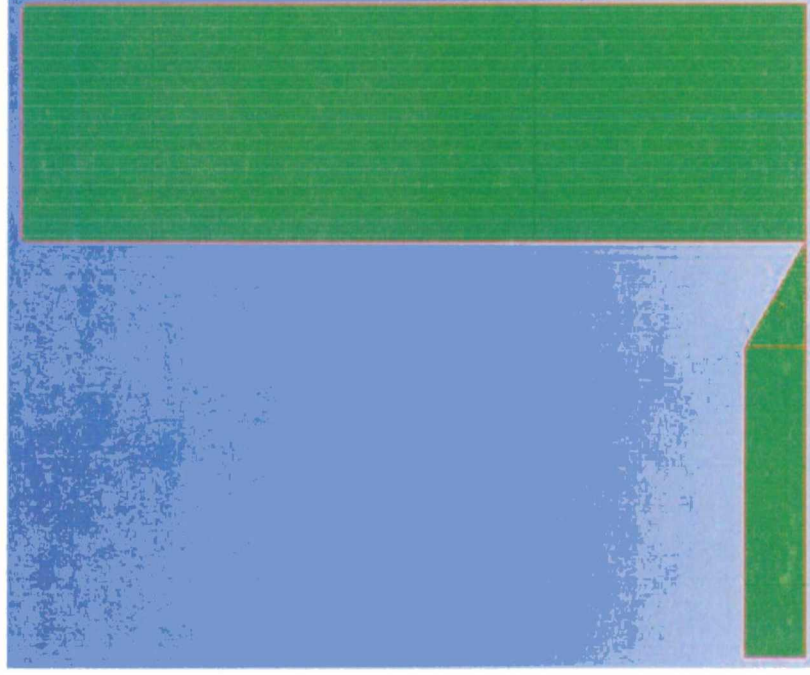
$$\theta = 30^\circ$$

Ceramic Target



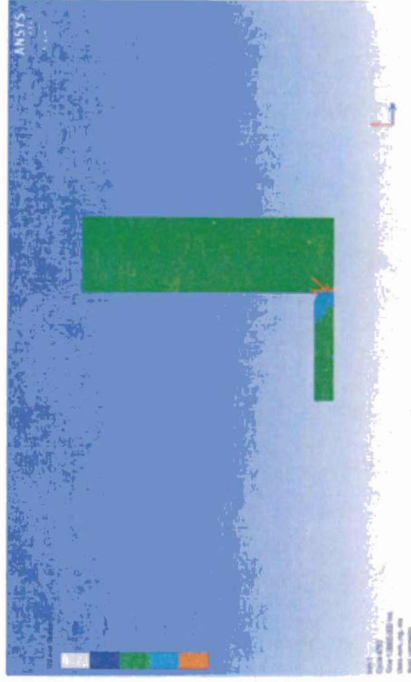


# Mesh Size Investigated

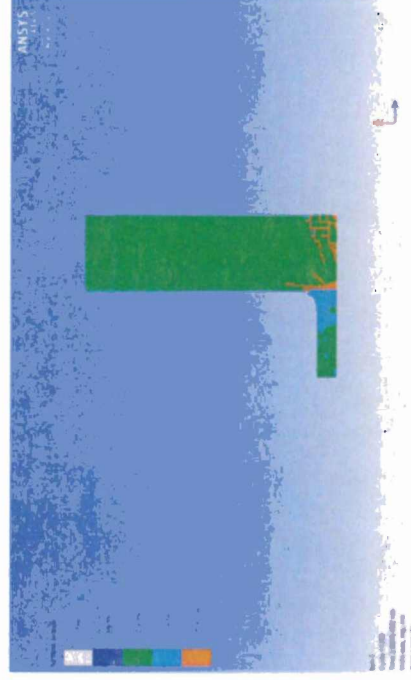


0.20-mm

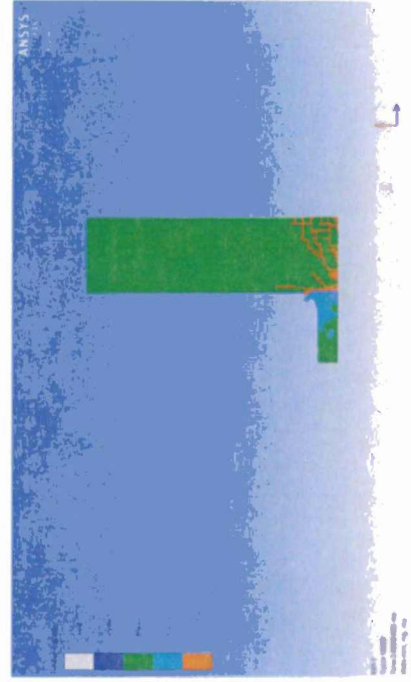
# Fracture Pattern for 0.20-mm Mesh



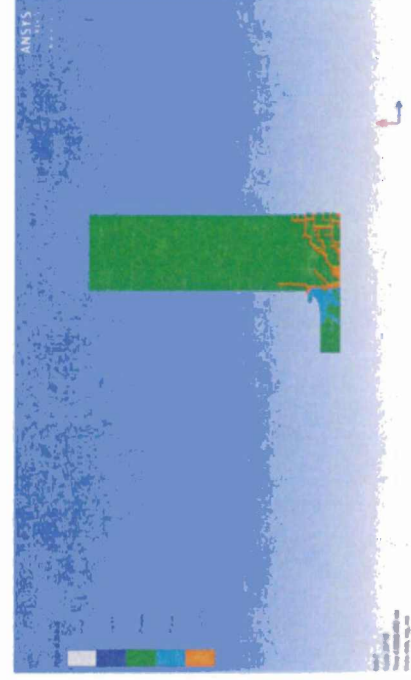
0.010-mm



0.020-mm



0.030-mm



0.040-mm